# Figure 1

# Figure 2



X1=(Si concentration/(Si concentration + Hf concentration)) × 100[%]

# Figure 3

| A | B |
|---|---|
| 750 | $\geqq 0.1$ |
| 800 | $\geqq 7.6$ |
| 850 | $\geqq 15.0$ |
| 900 | $\geqq 23.0$ |
| 950 | $\geqq 30.0$ |
| 1000 | $\geqq 37.5$ |
| 1050 | $\geqq 45.0$ |
| 1100 | $\geqq 52.4$ |

A:Maximum process temperature

B:Practical range of
　(Si concentration /(Si concentration + Hf concentration)) × 100[%],
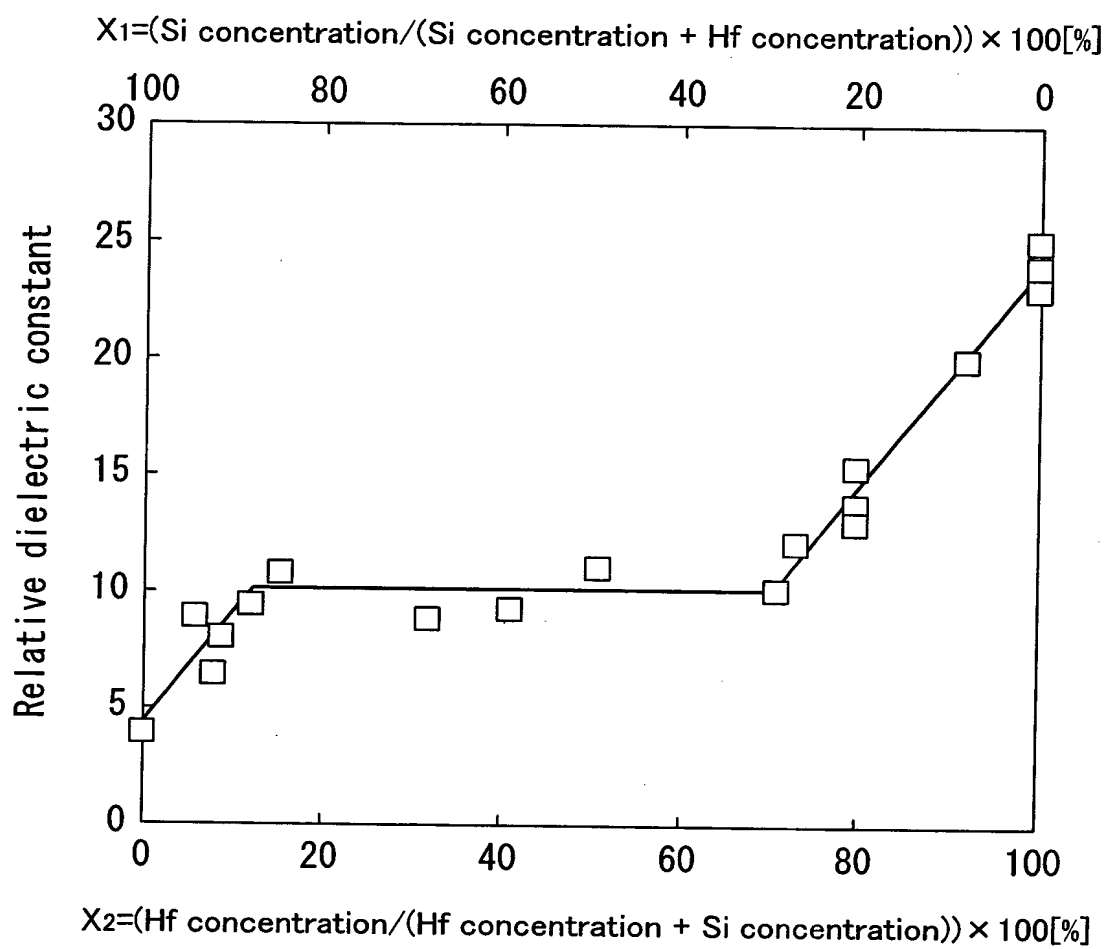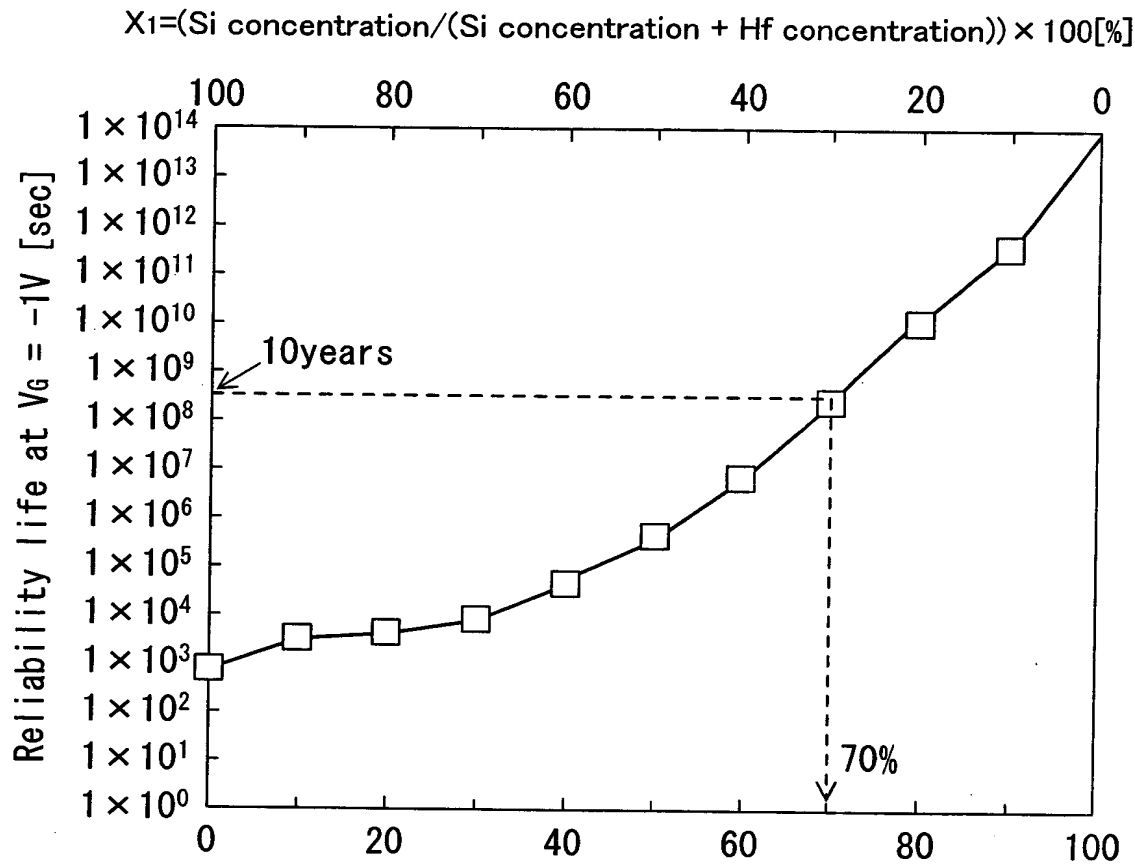　in which the thermal stability of Hf silicate can be ensured.

# Figure 4



X₁=(Si concentration/(Si concentration + Hf concentration)) × 100[%]

Relative dielectric constant

X₂=(Hf concentration/(Hf concentration + Si concentration)) × 100[%]

# Figure 5

X₁=(Si concentration/(Si concentration + Hf concentration))× 100[%]



Eox (real) model
  EOT=1. 5nm
  Incidence of failure=100ppm
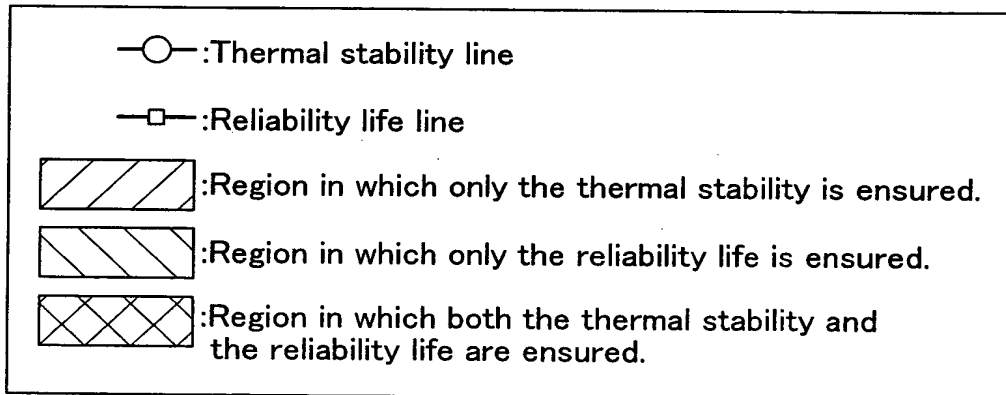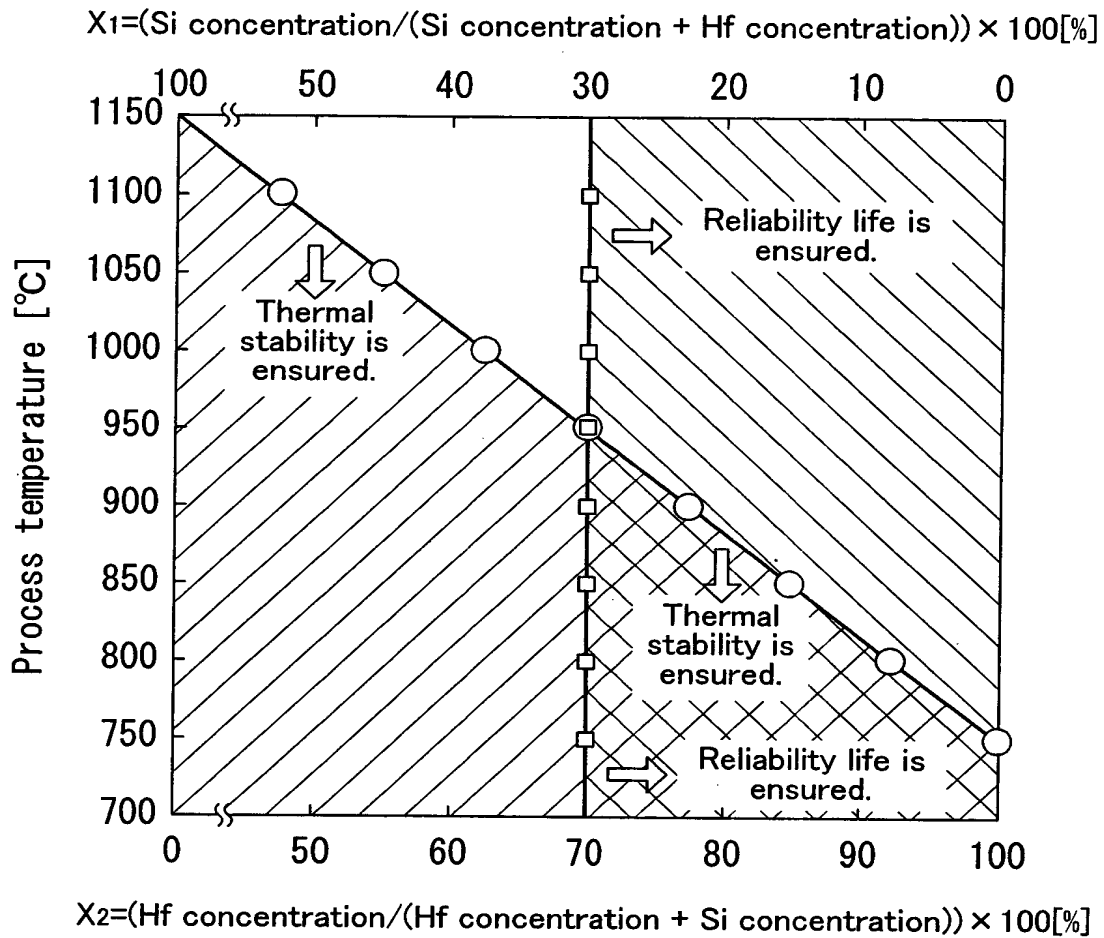  MOS area =0. 1cm²
  Temperature=100℃

# Figure 5

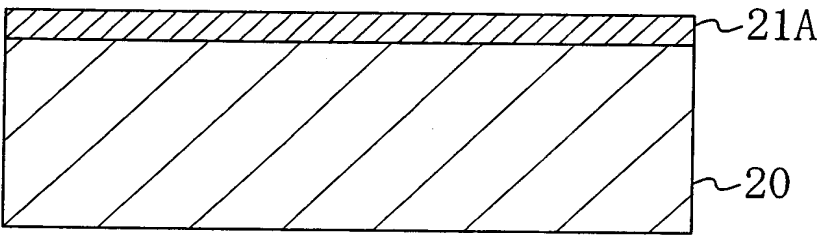$X_1$=(Si concentration/(Si concentration + Hf concentration))× 100[%]

Reliability life at $V_G$ = -1V [sec]

$1\times10^{14}$
$1\times10^{13}$
$1\times10^{12}$
$1\times10^{11}$
$1\times10^{10}$
$1\times10^{9}$
$1\times10^{8}$
$1\times10^{7}$
$1\times10^{6}$
$1\times10^{5}$
$1\times10^{4}$
$1\times10^{3}$
$1\times10^{2}$
$1\times10^{1}$
$1\times10^{0}$

10years

70%

$X_2$=(Hf concentration/(Hf concentration + Si concentration))× 100[%]

Eox (real) model
  EOT=1. 5nm
  Incidence of failure=100ppm
  MOS area =0. 1cm²
  Temperature=100℃

# Figure 6

$X_1=$(Si concentration/(Si concentration + Hf concentration)) × 100[%]



$X_2=$(Hf concentration/(Hf concentration + Si concentration)) × 100[%]

—◯— :Thermal stability line

—□— :Reliability life line

:Region in which only the thermal stability is ensured.

:Region in which only the reliability life is ensured.

:Region in which both the thermal stability and the reliability life are ensured.

# Figure 7A

21A

20

# Figure 7B

22A

21B

20

# Figure 7C

22

21

20

# Figure 8A



23
22
21

20

# Figure 8B



24
23
22
21

20

# Figure 8C



26

23
22  } 25
21

27

27

20

## Figure 9A

[before PDA]



~22A

~21B

## Figure 9B

[700℃PDA→hydrogen desorption]

H₂   H₂   H₂



~22A

~21B

## Figure 9C

[vacancy formation]



~22A

~21B

## Figure 9D

[Hf diffusion + Si diffusion]



~22A

~21B

# Figure 10

Density of hydrogen gas desorbed from the film
=5.6 × 10²⁰[molecules/cm³]

Temperature[°C]
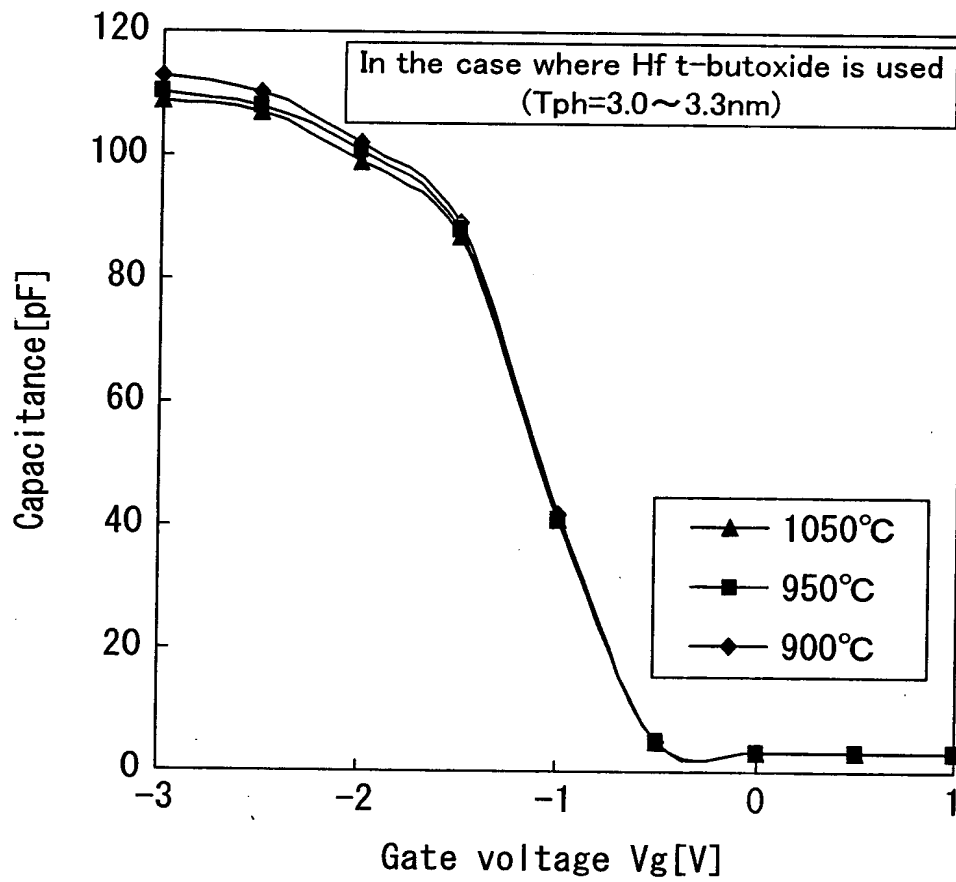
Spectrum intensity of H₂ gas measured by TDS [arbitrary unit]

# Figure 11

# Figure 12

# Figure 13

# Figure 14